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## **On Structuring the Rules of a Fuzzy Controller**

(summary)

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Since the pioneering work of Zadeh<sup>[1]</sup> and Mamdani and Assilian<sup>[2]</sup>, fuzzy logic control has emerged as one of the most active and fruitful research areas<sup>[3][4]</sup>. The applications of fuzzy logic control can be found in many fields such as control of steam generators, automatic train operation systems, elevator control, nuclear reactor control, automobile transmission control, etc.

In most of existing fuzzy rule-based controllers, the rules are based upon the error and the change in error, where the error is defined as the difference between the desired output and actual output. However in a large-scale system, the signals error and change in error only provide a limited amount of information about system status. Therefore, the performance of the controller will be limited, since only a fraction of the feedback information will be available to the controller. To avoid this limitation, the fuzzy rules need to be based upon more system variables. It is well known that the total number of rules in a complete rule set is an exponential function of the system variables on which the rules are based. As such when more system variables are used, the number of the rules will increase exponentially. This will make the fuzzy rule-based controller more complex as well as expensive to realize.

To make the problem manageable, the concept of a 'hierarchical fuzzy rule set' was introduced in reference<sup>[5]</sup>. In a hierarchically structured rule base, the number of rules

increases linearly (not exponentially) with the number of system variables. This makes it possible to apply a fuzzy rule-based controller to large-scale systems.

In this paper, two new structures of hierarchical fuzzy rule-based controller are proposed to reduce the number of rules in a complete rule set of a controller. In one approach, the overall system is split into sub-systems which are treated independently in parallel. A coordinator is then used to take into account the interactions. This is done via an iterating information exchange between the lower level and the coordinator level. Figure 1 schematically shows the main idea. From the point of view of information used, this structure is very similar to central structure in that the coordinator can have at least in principle, all the information that the local controllers have.

A more general structure of this approach is shown in Fig. 2, where more coordinate levels are introduced. By using this hierarchical structure, the theoretical minimum total number of rules will be a linear function of the system variables. The actual total is dependent upon the number of system variables used in each local controller's rule sets and coordinator's rule sets. Specifically, if we denote  $N$  as the total number of rules, then

$$N = \sum_{i=1}^{i=N_{1j}} m^{n_{1i}} + \sum_{i=1}^{i=N_{2j}} m^{n_{2i}} + \sum_{i=1}^{i=N_{3j}} m^{n_{3i}} + \dots$$

$$= \sum_{j=1}^J \sum_{i=1}^{i=N_j} m^{n_{ij}}$$

where  $N_j$  is the number of local controllers or coordinators in the  $j$ th level,  $n$  is the number of variables used in the  $i$ th local controller or coordinator in the  $j$ th level, and  $m$  is the number of the linguistic fuzzy variables used in each local controller or coordinator.

One important advantage of this approach over that in reference<sup>[5]</sup> is that all the rule

sets in the same level can be fired simultaneously. As such, this approach will be more suitable for parallel computing. However, using the structure in reference[5], additional system variables can be easily included in the fuzzy rule set without affecting other rules. A more versatile hierarchical structure, combining the hierarchical structure proposed in Fig. 2 and that in reference[5], will be presented in the paper. This versatile structure will have the advantages of all the structures discussed earlier.

### References

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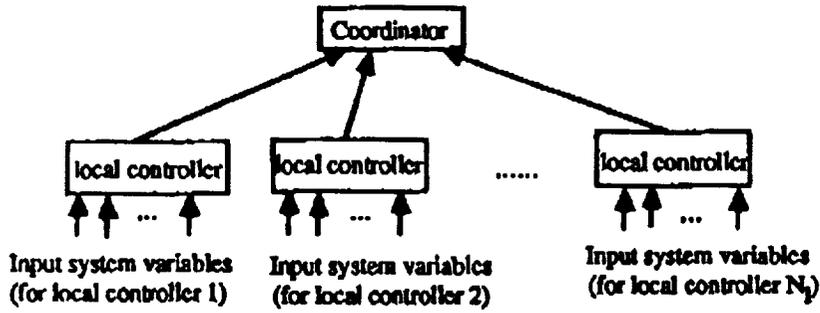


Fig. 1 Hierarchical structure of a controller with a coordinator and several local controllers

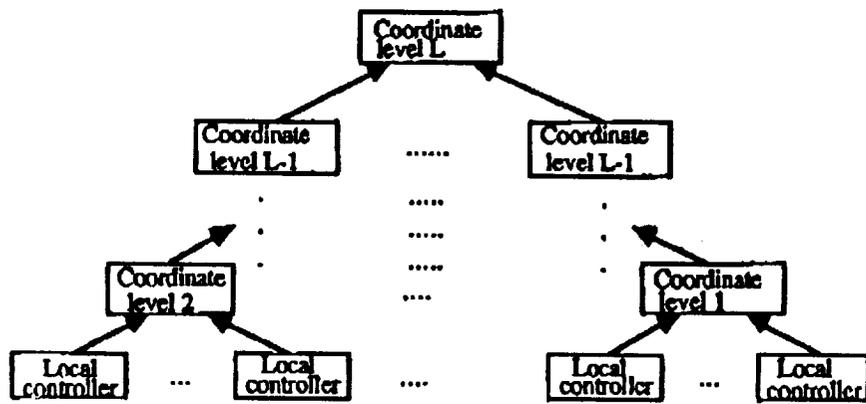


Fig. 2 A general structure of a hierarchical controller with several coordinate levels and a local controller level.